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THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY

SERIES ON THE SAFETY OF MANUFACTURED NANOMATERIALS
Number 9

EHS RESEARCH STRATEGIES ON MANUFACTURED NANOMATERIALS: COMPILATION OF OUTPUTS

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Series on the Safety of Manufactured Nanomaterials

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EHS RESEARCH STRATEGIES ON MANUFACTURED NANOMATERIALS: COMPILATION OF OUTPUTS

Environment Directorate
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
Paris, 2009

Also published in the Series of Safety of Manufactured Nanomaterials:

No. 1, *Report of the OECD Workshop on the Safety of Manufactured Nanomaterials: Building Co-operation, Co-ordination and Communication (2006)*

No. 2, *Current Developments/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 1st Meeting of the Working Party on Manufactured Nanomaterials (2006)*

No. 3, *Current Developments/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 2nd Meeting of the Working Party on Manufactured Nanomaterials (2007)*

No. 4, *Manufactured Nanomaterials: Programme of Work 2006-2008(2008)*

No. 5, *Current Developments/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 3rd Meeting of the Working Party on Manufactured Nanomaterials*

No. 6, *List of Manufactured Nanomaterials and List of Endpoints for Phase One of the OECD Testing Programme*

No. 7, Current Developments/ Activities on the Safety of Manufactured Nanomaterials: Tour de table at the 4th Meeting of the Working Party on Manufactured Nanomaterials

No.8, Preliminary Analysis of Exposure Measurement and Exposure Mitigation in Occupational Settings: Manufactured Nanomaterials

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The Inter-Organisation Programme for the Sound Management of Chemicals (IOMC) was established in 1995 following recommendations made by the 1992 UN Conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The participating organisations are FAO, ILO, OECD, UNEP, UNIDO, UNITAR and WHO. The World Bank and UNDP are observers. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participating Organisations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

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FOREWORD

The OECD Joint Meeting of the Chemicals Committee and Working Party on Chemicals, Pesticides and Biotechnology (the Joint Meeting) held a Special Session on the Potential Implications of Manufactured Nanomaterials for Human Health and Environmental Safety (June 2005). This was the first opportunity for OECD member countries, together with observers and invited experts, to begin to identify human health and environmental safety related aspects of manufactured nanomaterials. The scope of this session was intended to address the chemicals sector.

As a follow-up, the Joint Meeting decided to hold a Workshop on the Safety of Manufactured Nanomaterials in December 2005, in Washington, D.C. The main objective was to determine the "state of the art" for the safety assessment of manufactured nanomaterials with a particular focus on identifying future needs for risk assessment within a regulatory context.

Based on the conclusions and recommendations of the Workshop [ENV/JM/MONO(2006)19] it was recognised as essential to ensure the efficient assessment of manufactured nanomaterials so as to avoid adverse effects from the use of these materials in the short, medium and longer term. With this in mind, the OECD Council established the OECD Working Party on Manufactured Nanomaterials (WPMN) as a subsidiary body of the OECD Chemicals Committee. This programme concentrates on human health and environmental safety implications of manufactured nanomaterials (limited mainly to the chemicals sector), and aims to ensure that the approach to hazard, exposure and risk assessment is of a high, science-based, and internationally harmonised standard. This programme promotes international co-operation on the human health and environmental safety of manufactured nanomaterials, and involves the safety testing and risk assessment of manufactured nanomaterials.

This document is published on the responsibility of the OECD Chemicals Committee. It is intended to provide information on the outcomes and developments of the WPMN related to the safety of manufactured nanomaterials.

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THE WORKING PARTY ON MANUFACTURED NANOMATERIALS (WPMN)

1. The Working Party on Manufactured Nanomaterials[1] was established in 2006 to help member countries efficiently and effectively address the safety challenges of nanomaterials. OECD has a wealth of experience in developing methods for the safety testing and assessment of chemical products.

2. The Working Party brings together more than 100 experts from governments and other stakeholders from: a) OECD Countries; b) non-member economies such as Brazil, China, the Russian Federation, and Thailand; and **c**) observers and invited experts from UNEP, WHO, ISO, BIAC[2], TUAC[3], and environmental NGOs.

3. Although OECD member countries appreciate the many potential benefits from the use of nanomaterials, they wished to engage, at an early stage, in addressing the possible safety implications at the same time as research on new applications is being undertaken.

4. The Working Party is implementing its work through eight specific projects to further develop appropriate methods and strategies to help ensure human health and environmental safety:

- Development of a Database on Human Health and Environmental Safety (EHS) Research;
- EHS Research Strategies on Manufactured Nanomaterials;
- Safety Testing of a Representative Set of Manufactured Nanomaterials;
- Manufactured Nanomaterials and Test Guidelines;
- Co-operation on Voluntary Schemes and Regulatory Programmes;
- Co-operation on Risk Assessment;
- The role of Alternative Methods in Nanotoxicology; and
- Exposure Measurement and Exposure Mitigation.

5. Each project is being managed by a steering group, which comprises members of the WPMN, with support from the Secretariat. Each steering group implements its respective "operational plans", each with their specific objectives and timelines. The results of each project are then evaluated and endorsed by the entire WPMN.

6. This document comprises output documents that have been produced during the course of the work of the project on EHS Research Strategies on Manufactured Nanomaterial.

[1] Updated information on the OECD's Programme on the Safety of Manufactured Nanomaterials is available at: www.oecd.org/env/nanosafety

[2] The Business and Industry Advisory Committee to the OECD

[3] Trade Union Advisory Committee to OECD.

PROJECT ON EHS RESEARCH STRATEGIES ON MANUFACTURED NANOMATERIALS

1. The project on **EHS Research Strategies on Manufactured Nanomaterials** was established to exchange information on research activities and identify common research needs to address human health and environmental safety issues associated with manufactured nanomaterials and to undertake to meet those research needs. Nevertheless, the project is not intended to develop a global harmonised research strategy, nor to actively co-ordinate existing or future research activities; but rather to provide information on the research status quo at the national level, while identifying common research needs.

2. With this in mind, the project proceeded in several stages and developed several research status documents, based on information provided by delegations: i) a list of research themes relevant to EHS of nanomaterials; and ii) an overview on completed, current or planned research activities as well as urgent and medium/long term research priorities. With further analysis, the interim report for the project was written and discussed at the 4th meeting of the WPMN, 11-13 June 2008 in Paris. The interim report included the outcomes of what the project had achieved until then; identification of research themes with a high coverage already today ("hot spots"); a suggested mechanism for co-ordination of those activities in order to avoid overlaps and/or duplication; identification of research areas that are adequate for international co-operation; and recommendations for draft data sharing formats and requirements to facilitate exchange of research results.

3. The project concomitantly recognized that current available information on existing research projects and research strategies is too limited and heterogeneous to adequately address identifying common research needs and undertaking to meet those research needs.

4. This document comprises the compilation of output documents that have been produced during the course of the work of the project, and that can be useful to a wider audience, in addition to the WPMN. Each document is based on the responses from delegations to *the Questionnaire for National Authorities (and other delegations to the WPMN) Responsible for the Safe Use of Manufactured Nanomaterials*.

5. More information about the work of the WPMN, as well as publications and updates on efforts of governments and other stakeholders to address safety issues of nanomaterials is available at http://www.oecd.org/env/nanosafety .

LIST OF RESEARCH THEMES RELEVANT TO HUMAN HEALTH AND ENVIRONMENTAL SAFETY OF NANOMATERIALS

Background

1. The list of research themes aims to highlight the relevant subjects regarding human health and environmental safety research of nanomaterials. In this context, research is defined in a broader sense. It considers not only experimental studies, but also *e.g.* evaluation of available literature, database generation, comprehensive risk assessment of specific substances, international standard setting, public dialogue, etc. All the research that requires funding might be addressed. This is also a living list of research themes to be adapted with increasing experience.

2. This list is targeted at fulfilling the objective of Project Two: *Research Strategies on Human Health and Environmental Safety of Manufactured Nanomaterials*. On the other hand, it has assisted the development of the OECD research database on human health and environmental safety research by providing key research words. This list can also help Member States, Industry and NGOs to develop research activities, research plans or strategies.

Research themes

1. Characterisation and measurement of nanomaterials

1.1. Physico-chemical properties

- Research for the development of characterisation methods as necessary
- Physico-chemical characterisation (incl. flammable, combustible, explosive, oxidising pyrophoric properties, etc.)
- Physico-chemical classification
- Definitions, standardisation
- Preparation of reference standards (neat, in commercial forms, in matrices)

2. Exposure assessment for humans and the environment

2.1. Research for the development and validation of exposure measurement and exposure modelling[4] methods for nanomaterials

- Research for the development and testing of measurement methods including instruments (based on measurement parameters relevant for human health hazards; see 4.1.1)
- Validation[5] and standardisation of measurement methods (incl. measurement strategy, standardized sampling methods)
- Research for the development and testing of exposure modelling methods
- Validation of modelling methods (incl. sensitivity analysis)

4 In lack of measurements preliminary assumptions on exposure can be calculated by models

5 validation includes conclusions on qualitative and quantitative minimum acceptance criteria

Primary fields of application:

- At workplaces
- In foods (as well as feed)
- In consumer products (food contact material, cosmetics, clothing, health care products and other consumer products)
- In biological material
- In the environment
- In wastes and environmental releases

2.2. Human Exposure Assessment
Application of exposure measurement and modelling methods on nanomaterials

- Identification of nanomaterials that are produced and marketed (incl. production volume, methods of production and processing, uses and application): determined through surveys, reporting schemes
- Measurement of exposure (workers, consumers)
- Modelling of exposure (workers, consumers)
- Categorisation of exposure
- Consideration of the full life cycle and development of exposure scenarios of nanomaterials

2.3. Environmental Exposure Assessment

- Consideration of the full life cycle and development of exposure scenarios of nanomaterials, based on physico-chemical (PC) and biological properties
- Examination of behaviour and fate (accumulation and persistence including modelling approaches) in the environment (air, water, soil, sediment, sewage / sewage sludge) and biological endpoints of concern along the food chain such as zooplankton, filter-feeding organisms, fish and wildlife)
- Formation of possible degradation / transformation products in biota
- Partitioning of nanomaterials and their degradation products in the environment (incl. agglomeration)
- Examination of long-term fate of nanomaterials in use and post-use lifecycle stages (e.g. erosion, abrasion/ wear, leachability, in-place degradation)
- Ability to act as carrier for other substances
- Evaluation of characteristics (and industrial processes) affecting release, fate and transport
- Establishment of environmental detection and monitoring protocols, incl. techniques to differentiate between manufactured and naturally occurring nanomaterials, and incl. development of techniques to detect long term fate of nanomaterials in individuals, populations, and ecosystems.
- Development of structure-activity relationships to assist in predicting the behaviour and fate of nanomaterials in various media and biota

3. Interaction of nanomaterials with biological systems (human and environment)

Biological interactions should be explored for single particles, agglomerates and aggregates over the life cycle of the nanomaterials.

3.1 Interaction with normal physiological mechanisms

- Interaction with biological molecules: DNA, proteins, lipids
- Interaction with the cellular surface (cell membranes, plant cell wall, bacterial wall)
- Molecular, cellular and organ system mechanisms
    - Mitosis
    - Apoptosis/necrosis
    - Inflammation
    - Oxidative stress
    - Immune response
    - Mutagenicity/DNA repair
    - Mitochondrial function
    - Cell binding, cell internalisation (endocytosis)

3.2 Toxicokinetics

- Bioaccumulation/biotransformation
- Adsorption, distribution (incl. translocation), metabolism, elimination
- Effect of synthesis byproducts on absorbed dose
- Relationship between the matrix in which nanomaterials are suspended or administered and absorbed dose

3.3 Inter- and intraspecies variability

- Susceptible populations
    - Age and developmental status
    - Health status / pre-existing diseases
    - Genetic predisposition
- Extrapolation between species and from in vitro studies and animal models to humans (see 4.1.1)
- Extrapolation between species and from in vitro studies to ecosystem and population

3.4 Predictive models

- Physiology-Based Pharmacokinetic (PBPK) models
- Structure Activity Relationships (SAR)
- Computational approaches
- Models which address a variety of ecosystem types and predict long term possible effects of manufactured nanomaterials on ecosystem structure and function.

3.5 Long term monitoring and assessment of condition

- Using established detection and monitoring protocols, assess the condition of individuals (human and ecological), populations (human and ecological), and ecological systems over the long term.

4. Human Health

4.1 Research for the development and validation of a testing and assessment strategy

4.1.1 Determination and validation of measurement parameters (dose metrics) relevant to assess human health hazards

Validation implies the assessment of predictivity (sensitivity and specificity) of test results and the definition of minimum qualitative and quantitative acceptance criteria

- Studies on physico-chemical (PC) properties
- *In vitro* effects
- *In vivo* effects

4.1.2. Test methods

- Toxicological endpoints:
    - Acute toxicity
    - Repeated dose toxicity
    - Irritation/corrosion
    - Immunotoxicity/sensitisation
    - Mutagenicity
    - Carcinogenicity
    - Developmental toxicity (incl. endocrine disruption)
    - Fertility impairment
- Research for the development and validation of standardised testing methods: including guidance on preparing materials for studies (e.g. aerosol generation, solubilisation), sampling methods, positive and negative reference materials
- Determination of relevant exposure routes (based on exposure assessment)
    - Inhalation exposure (e. g. workplace)
    - Dermal exposure (e. g. cosmetics, workplace)
    - Oral exposure (e. g. foods and food packaging materials)
- Research for the development of minimum requirements for information in publications

4.1.3. Categorisation and derivation of conclusions

- Guidance on how to perform a risk assessment, how to consider PBPK-modelling, how to derive conclusions, control measures (exposure limits, etc.) including minimum acceptance criteria for the application
- Assignment of nanomaterials to categories of different toxicity through in vitro and in vivo studies and studies on PC properties

4.2. Application of a testing strategy and assessment strategy

- Comparative studies on representative nanomaterials with widespread exposure (e. g. based on production volume)
    - Specific coating/derivates agglomeration/aggregation needs differentiation, studies on the respective non-nanoparticulate fine particles should be considered
    - Zinc oxide
    - Titanium dioxide
    - Carbon black
    - Silica dioxide (amorphous, crystalline), silicates
    - Aluminium oxide
    - Silver
    - Further substances
- Studies with new nanomaterials with expected future importance
    - Carbon nanotubes (single wall, multi wall, including derivates)
    - Fullerenes (including derivates)
    - Quantum dots
    - Dendrimers calixarenes
    - Macromolecular entities
    - Supramolecular entities
    - Light and electromagnetic active nanomaterials
    - Highly functionalised organic nanomaterials
    - Further substances
- Kind of study
    - *In vitro* studies
    - *In vivo* studies in animals
    - Human data (occupational medicine, epidemiology, case studies)
- Risk assessment
    - Conclusions on classification, labelling
    - Conclusions of exposure limits
    - Conclusions on handling and use

4.3 Co-exposure with other substances/Toxicology of mixtures

- Effects of agglomeration and interaction with natural and non-intentionally produced nanomaterials
- Studies with the product of attrition from nanocomposites
- Effects of organic materials and other chemicals, such as those found in air pollution, that may be adsorbed to nanomaterials and change their toxicity
- Determination of nanomaterials as a carrier for other substances
- Characterisation of physicochemical changes after administration due to interactions with the biological media

5. Ecotoxicology

5.1. Research for the development and validation of a testing and assessment strategy

- Analysis of conducted studies with regard to relevant endpoints, elaboration of action hypotheses, identification of suitable test systems and positive and negative reference materials
- Research for the development of minimum requirements for information in publications
- Examination, adjustment and validation of ecotoxicological test methods and standardisation of nano-specific test systems (terrestrial and aquatic)
- Elaboration and examination of test strategies (terrestrial and aquatic)
- Elaboration of an assessment strategy to determine the environmental risk of nanomaterials (Technical Guidance Document: Risk characterisation)
- Evaluation of mechanisms / mode of action of ecotoxicity of nanomaterials (e.g. related proteomics and genomics studies)
- Guidance on preparing nanomaterials for ecotox studies (e.g. aerosol generation, solubilisation and chemical reactivity)
- Effects of agglomeration and interaction with other materials and other physical or chemical stressors in ecotox studies
- Studies on which dose-metrics are adequate to determine environmental hazards of nanomaterials by ecotox tests
- Grouping of nanomaterials by ecotoxicological effects

5.2. Application of testing and assessment strategy

Comparative studies on representative nanomaterials with widespread exposure (e. g. based on production volume, toxicity of bulk material, exposure path). Specific coating, agglomeration/aggregation need to be considered. Studies on the respective non-nanoparticular fine particles should be included in the comparison. An appropriate subset of organisms from major biomes representing keystone species or those that influence key ecological processes and functions should be selected for testing.

  - Zinc oxide
  - Titanium dioxide
  - Carbon black
  - Silica dioxide (amorphous, crystalline), silicates
  - Aluminium oxide
  - Silver
  - Further substances
- Studies with new nanomaterials with expected future importance
  - Carbon nanotubes (single wall, multi wall, including derivates)
  - Fullerenes (including derivates)
  - Quantum dots
  - Dendrimers calixarenes
  - Macromolecular entities
  - Supramolecular entities
  - Light and electromagnetic active nanomaterials
  - Highly functionalised organic nanomaterials
  - Further substances

- Kind of study
    - *In vitro* studies
    - *In vivo* studies in animals, plants and microorganisms to assess lethal and sublethal effects
    - Mesocosm studies to assess interactions and indirect effects of manufactured nanomaterials among individuals, populations and ecological processes.
- Risk assessment
    - Conclusions on classification, labelling
    - Conclusions of emission and exposure limits
    - Conclusions on handling and use
    - Develop risk assessment models, which will likely incorporate SAR information, that address a variety of ecosystem types and predict long term possible effects of manufactured nanomaterials on ecosystem structure and function.

6. Control measures in the workplace

6.1. Research for the development and validation of methods to evaluate control measures at workplaces

- Research for the development and testing of measurement methods (see 1.2)
- Validation and standardisation of measurement methods

Primary fields of application are:

- Technical measures (closed system, air filters, controlled atmospheres, cleaning and waste disposal procedures)
- Organisational measures
- Personal protective equipment (filter masks, gloves, suits)

6.2. Application of methods to evaluate control measures at workplaces

- Technical measures (e.g. closed system, air filters, controlled atmospheres, cleaning and waste disposal procedures)
- Organisational measures
- Personal protective equipment (e.g. filter masks, gloves, suits)

6.3. Control banding approach

- Research for the development and validation of the control banding approach to cover nanomaterials

7. Preliminary handling guidelines

- Primarily based on technical feasibility
- Collection of available and ongoing approaches
- Evaluation and further development

8. Information transfer

- Database generation
- Public dialogue:
  - Identification and assessment of the positive and negative effects of nanotechnology development on the environment, health and safety
  - Research for the development of dialogue offerings as well as initial and continuing training initiatives
  - Identification and quantification of the impact of nanotechnology on society, industry, workplaces, education, ethics and the legal system.
- Information to and training of workers, information to business and employers (MSDS, fact sheets)

9. National and international collaboration

Co-ordination and co-operation at international level should be actively sought particularly in view of:

- Development
- Testing
- Validation
- Standardisation
- Assessment activities

ANALYSIS OF THE FREQUENCY OF ENTRIES IN THE LIST OF CURRENT/COMPLETED AS WELL AS PLANNED RESEARCH PROJECTS

Objective

1. The project on **EHS Research Strategies on Manufactured Nanomaterials** aims at, amongst others, i) identification of research priorities for the short, medium and longer term, and ii) consideration of mechanisms for co-operative international research. *The Compilation of Completed, Current and Planned Research Projects*, based on the responses from delegations to the questions on research activities on the safe use of manufactured nanomaterials, provides an overview of respective activities in member countries, the EC, and industry. The analysis of the frequency of entries for each research theme, based on the list of research themes identified by the project, identifies "hot spots", i.e. research themes with a high coverage already today, as well as "gaps", i.e. research themes that are not covered frequently today and may need further coverage in the future.

2. "Hot spots" may be recommended for international co-ordination of research to avoid duplication due to overlaps. "Gaps" may be recommended for co-operative international research in the medium and longer term to facilitate sharing of resources and burden.

3. However, it has to be kept in mind that this analysis, due to the limitations of the available information, neither takes into account the size or volume (funding) of the research, nor the quality (outcomes, conclusions accepted in the scientific or regulators community, etc.). Therefore, identification of "hot spots" or "gaps" should be understood as a recommendation to focus further analysis onto those topics, but not as a final conclusion or assessment.

4. In addition, this includes the frequency of entries for each nanomaterial used for application of testing methods and strategies, resulting in a prioritization. This prioritization may be helpful for the Sponsorship Program to co-ordinate the measurement of representative nanomaterials[6].

Results

5. Table 1 shows the profile of the number of entries against the research themes.

Hot spots

6. Five "hot spots" can be identified:

- Characterisation of physical-chemical properties: size, shape, surface area, surface chemistry, aggregation, solubility, wetability, dispersability, etc.
- Research for the development and validation of exposure measurement and exposure modelling methods for nanomaterials in the environment

[6] The Sponsorship Programme is an international effort to share the testing of representative nanomaterials selected by the OECD Working Party on Manufactured Nanomaterials.

- Interaction with the cellular surface (cell membranes, plant cell wall, bacterial wall)
- Molecular, cellular and organ system mechanisms
- Adsorption, distribution (incl. translocation), metabolism, elimination

Followed by

- Research for the development and testing of measurement methods including instruments
- Identification of nanomaterials that are produced and marketed (incl. production volume, methods of production and processing, uses and application): surveys, reporting schemes
- Measurement of exposure (workers, consumers)
- Consideration of the full life cycle and development of exposure scenarios of nanomaterials
- Interaction with biological molecules: DNA, proteins, lipids
- Bioaccumulation/biotransformation
- Human health - determination and validation of measurement parameters (dose metrics) relevant to assess human health hazards: in vitro effects
- Human health - test methods: inhalation exposure (e. g. workplace)
- Identification and assessment of the positive and negative effects of nanotechnology development on the environment, health and safety
- National and international collaboration on testing

Trends

7. Independently from the hot spots, general trends for the prioritization of completed, current and planned research themes can be concluded:

- The highest priority currently is on the basic mechanisms of interaction of nanomaterials with biological systems, i.e. in vitro testing (however, more sophisticated approaches are of very little priority, e.g. genetic predisposition, human health status, susceptible populations, etc.);
- Currently, human health in general is of higher priority then environmental safety. This is also true regarding exposure analysis;
- Research with respect to the environment is at an early stage. High scorings are on the development and validation of exposure measurement methods and analysis of conducted studies. However, less attention is put on the application of testing methods and strategies yet; and
- Remarkable attention is also given to issues of information transfer (e.g. databases, public dialog) as well as international research coordination.

Nanomaterials

8. Frequencies of entries with respect to the nanomaterials used for the application of human health and environmental testing methods and strategies result in the following ranking:

	Human health	Environment
1.	Carbon nanotubes	Carbon nanotubes
2.	Titanium dioxide	Titanium dioxide
3.	Carbon black, Silica dioxide	Carbon black, Silver, Fullerens
4.	Silver, Zinc oxide, Quantum dots	Silica dioxide, Zinc oxide
5.	Fullerenes	Quantum dots
6.	others	others

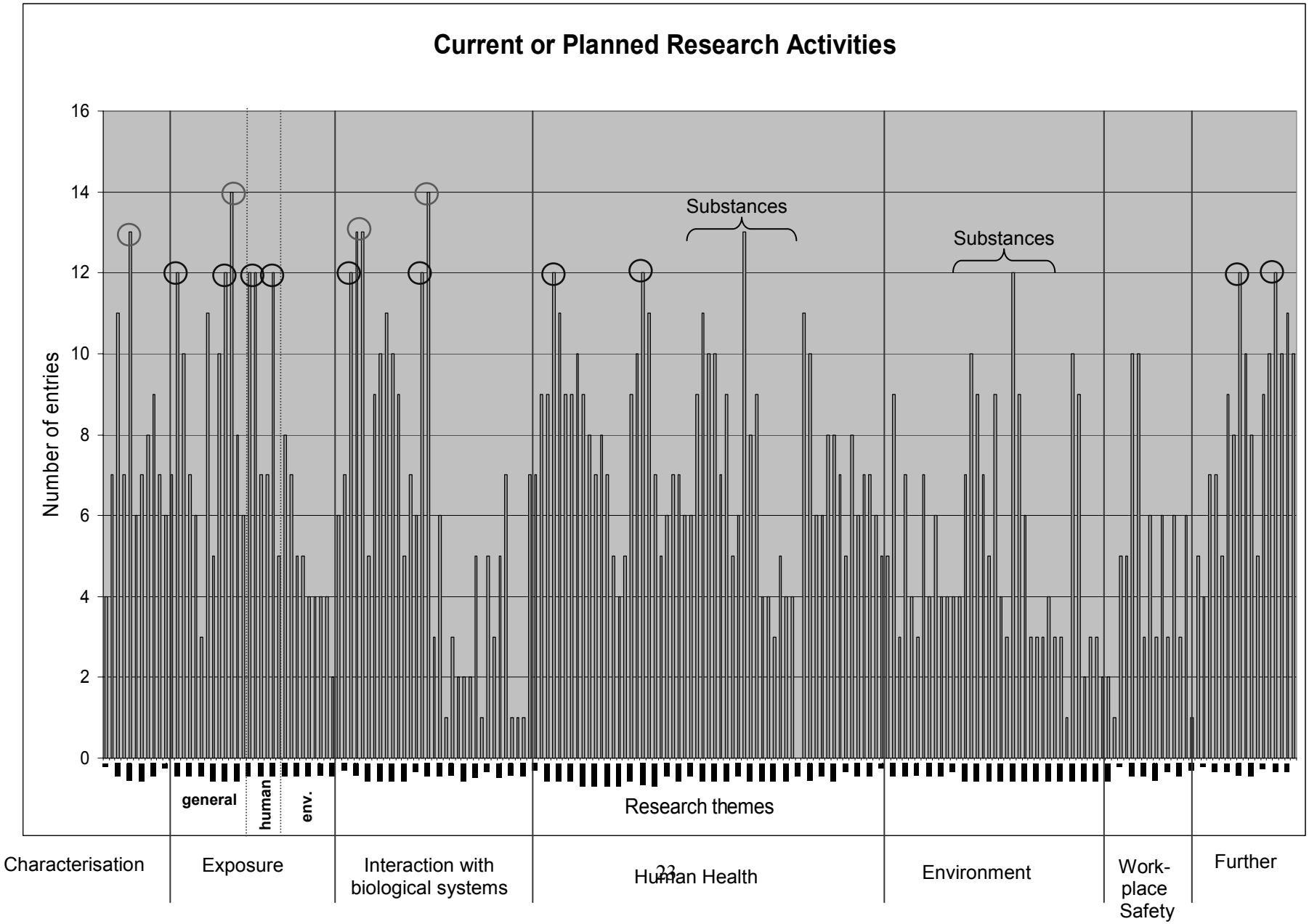
9. The above analysis shows that about five to more than ten countries already have completed, current, and planned research activities with respect to the top five nanomaterials. The Sponsorship Programme [ENV/CHEM/NANO(2008)5] for testing nanomaterials initiated by the WPMN is inviting sponsors for testing each representative nanomaterials identified[7]. However, all interested parties are encouraged to provide relevant information and to participate in the preparation of the dossiers for those substances. Thus, it seems recommendable to ensure international coordination of those activities with respect to the Sponsorship Programme and beyond.

Gaps or Sequential Priority

10. The information available in the list of current, completed or planned research activities would probably be over interpreted, if one would try to conclude defined research gaps from this list, since the list does not contain information on research projects itself. This information will be provided soon by the OECD EHS research database. Nevertheless, based on the results of the analysis of the frequency of entries in the list of completed, current and planned research themes discussed above, and assuming that research themes currently given less priority (e.g. environmental and workplace safety) are not *per se* less important, one may conclude sequential priority of research themes defining a "workflow".

11. It shows that current research is more or less focussed on the understanding of the physiologically relevant interaction of nanomaterials with biological systems *in vitro* (cells, molecules, tissue) and the evaluation, adjustment and development of testing methods and strategies with respect to human health. Physical-chemical characterisation seems to be selectively covered as needed as well as exposure assessment methodology. Future research should additionally cover application of testing methodology regarding human health and respective efforts regarding ecotoxicology. Finally, conclusions will need to be taken with respect to occupational as well as consumer health and environmental safety.

[7] See the document ENV/JM/MONO(2008)13 for more information.


Current or Planned Research Activities
Number of entries
16
14
12
10
8
6
4
2
0
Substances
Substances
general
human
env.
Research themes
Characterisation
Exposure
Interaction with biological systems
Human Health
Environment
Work-place Safety
Further